THE C-, N-, AND O-ISOTOPIC COMPOSITION OF COMETARY DUST FROM COMET 81P/WILD 2. J. Leitner[1], P. R. Heck[2], P. Hoppe[1], and J. Huth[1], [1]Max Planck Institute for Chemistry, 55128 Mainz, Germany (jan.leitner@mpic.de), [2]Robert A. Pritzker Center for Meteoritics and Polar Studies, Dept. of Geology, Field Museum, Chicago, IL, USA.

Introduction: NASA's Stardust mission collected dust particles from the coma of comet 81P/Wild 2 in 2004 and returned to Earth in 2006 [1]. Besides low-density Si-based aerogel, aluminum foil provided a second valuable capture medium for cometary dust particles [1,2]. Impactor residues are typically found inside crater cavities or on crater rims. Preliminary examination revealed the dust to be an unequilibrated mixture of heterogeneous material of mainly solar system isotopic composition [2,3]. Three ^{17}O-rich presolar silicate/oxide grains and one presolar SiC grain have been reported previously, as well as an ^{18}O-enriched signature of likely supernova origin within a crater residue [3–8].

Samples and Experimental: In this ongoing study, 1334 small impact craters (d=0.09–4.4 µm) were found in a SEM high-resolution survey on Stardust aluminum foils C2013N, C2037N, C2044W, C2052N, C2086N, and C2126W . Qualitative EDX spectra were obtained from 306 craters with a LEO 1530 FE-SEM at an extraction voltage of 5 kV to minimize background effects from the target Al foil. Impact residues in 236 small craters (d=0.24–1.76 µm) were investigated for their O-isotopic compositions; additionally, the C- and N-isotopic compositions of 20 small craters (d=0.32–1.86 µm) were determined. For the isotope measurements a ~100 nm primary Cs^+ beam was rastered over 2×2 µm²- to 10×10 µm²-sized sample areas in the NanoSIMS 50 at the MPI for Chemistry. For the O-isotopic analyses, $^{16,17,18}O^-$, $^{28}Si^-$, and $^{27}Al^{16}O^-$ ion images were acquired in multi-collection mode. Presolar signatures are identified in situ by their O-isotopic composition, while detection of $^{28}Si^-$ facilitates the identification of the most common types of crater residues. For C- and N-isotopic investigations, $^{12,13}C^-$, $^{12}C^{14}N^-$, $^{12}C^{15}N^-$, and $^{28}Si^-$ ion images were acquired, ^{28}Si serving again as tracer for the crater residues.

Results: *EDX measurements*. We obtained useful qualitative EDX spectra for 305 craters. A quantitative analysis is difficult due to several issues. Foil impurities containing Mg, Si, Ca, or Fe can contribute to the measured element abundances; quantification of spectra recorded with 5 kV acceleration voltage requires correction factors for several elements (Mg, Si, Fe). For S, the situation is even more complicated, since a fraction of this element within the impacting particles has been volatilized during foil impact. Such effects complicate the analysis of large impact crater residues [9,10], and are even more severe for small (d < 5µm) craters. Therefore, we divide the EDX spectra into different types, and extended the original classification used in [2]. In addition to the Type I-III spectra (FeS dominant; silicates with low FeS; silicates & FeS admixed), we found 10 craters that were dominated by carbonaceous material and are classified as Type IV. Nearly 98 % of all investigated crater residues can be distributed into these 4 groups.

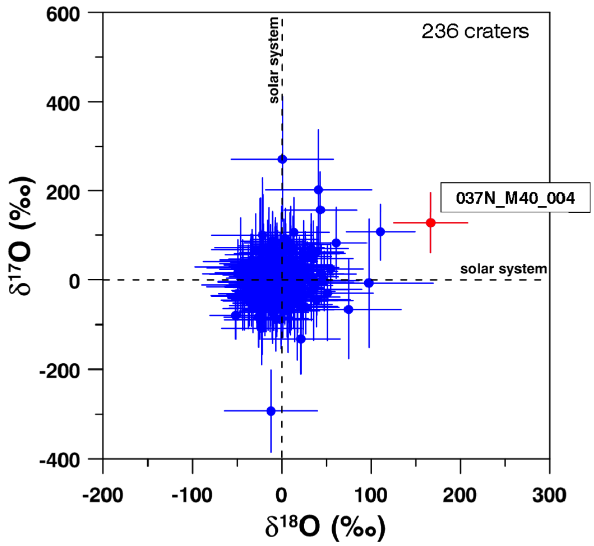

Fig. 1. *Oxygen 3-isotope-plot (in delta notation) showing data for 236 investigated crater residues. The presolar residue, 037N_M40_004, is marked in red.*

Isotopic analyses. In addition to the 6 craters on foil C2037N that were reported in [3] and [5], the C- and N-isotopic compositions of 14 small (d=0.32–1.24 µm) craters on foil C2013N were determined. No residues with anomalies >4σ (our criterion for a presolar signature) were found. All reported errors are 1σ. $\delta^{13}C$ ranges from –234±74 ‰ to +106±35 ‰, and the $\delta^{15}N$-values spread from –474±151 ‰ to +579±305 ‰. Among the 236 craters analyzed for O-isotopes (total residue area ~86 µm²), we identified one presolar signature [8] (Fig. 1). Oxygen isotopic compositions of the isotopically "normal" craters range from –294±93 ‰ to +272±140 ‰ for $\delta^{17}O$ and from –52±52 ‰ to +111±38 ‰ for $\delta^{18}O$ (normalized to foil contaminations of solar system isotopy), complying with solar system isotopy within 3σ. One crater on foil C2037N, 37N_M40_004, has a $\delta^{18}O$ of 167±41 ‰. The ^{18}O-

anomaly is distributed nearly all over the crater area and meets a 4σ-criterion. The three presolar silicate/oxide grains reported by [3–5] all belong to the O-isotope group 1, most likely originating from low-mass AGB stars. The ^{18}O-enriched residue falls into group 4 and has probably formed in the ejecta of a Type II supernova [11,12]. 37N_M40_004 is about 700 nm in size; a correlation between crater diameter and the diameter of the projectile is given in [13]: $D_{crater}/D_{projectile} = 1.60 \pm 0.17$ for $D_{projectile} < 2.4$ µm. From this we infer a projectile diameter of ~400 nm.

Discussion: Characterization of the crater residues by EDX allows to focus the O-isotopic measurements on those impactors that contain significant amounts of silicates (i.e., O-bearing material); and, moreover, the comparably rare carbonaceous Type IV craters can be selected for C- & N-isotopic measurements.

Upon foil impact, melting of projectile material occurs to varying degrees [14], which suggests that the results of investigations of large (d>2 µm) foil craters underestimate the content of presolar grains in the cometary dust. Even large isotopic anomalies of melted particles with diameters of 300 nm (the average size of a presolar silicate grain) are not detectable if they were part of larger normal grains that formed craters larger than 2µm. Therefore, we can minimize these dilution effects by investigating small impact craters, and, with sufficient statistics, a more realistic estimate of the presolar grain abundance in Wild 2 matter can be made. The current estimate on the abundance of presolar grains in matter from Wild 2 bears large uncertainties; >90 percent of the investigated matter is located in impact craters with d>20 µm. For a proper calculation of the presolar matter abundance in Wild 2 dust, we need reliable information about the fraction of melted presolar grains within the residues.

The probability of finding one presolar residue among 236 investigated craters per chance is below 3 ‰, if the abundance of presolar grains is ~11 ppm [5,15]. However, because of the dilution effect, it is very likely that the true abundance is much higher. Our best estimate for the abundance of presolar O-amomalous grains in Wild 2 can be calculated by dividing the original presolar grain's volume (d=300 nm assumed) by the total volume of small crater residue of solar system composition. This yields an abundance of ~1100 ppm. We point out that our estimate for Wild 2 bears large uncertainties because it is based on the identification of only one presolar grain so far.

Our abundance estimate is a bulk-normalized value, while abundances for primitive meteorites are based on in situ analyses of polished sections and are therefore commonly reported as matrix-normalized values. When translating matrix-normalized values from meteorites with the highest presolar silicate abundances [16–18] into bulk-normalized abundances we obtain values ≤66 ppm. Antarctic micrometeorites (AMM) show a similar abundance (57 ppm) for presolar silicates and oxides [19]. The ^{15}N-rich 'primitive' subgroup of interplanetary dust particles (IDPs) has an average bulk-normalized presolar grain abundance of 375 ppm [20], while IDPs from the "Grigg-Skjellerup collection", which most likely originate from comet 26P/Grigg-Skjellerup, have an average presolar silicate abundance of 500 ppm, with up to 1.5 % for individual particles [21]. The inferred bulk-normalized presolar O-anomalous grain abundance of 1100 ppm for small crater residues of 81P/Wild 2 particles lies therefore above the range of abundances reported for other primitive materials of possible cometary origin.

Conclusions: Even if we consider the still large uncertainties of our abundance estimate, investigation of the residues of small impact craters on Stardust Al foil, allows to make a realistic estimate of the abundance of presolar material in 81P/Wild 2. There is clear evidence coming from our work that it is significantly higher than previous calculations indicated. To increase the significance of our abundance estimate we need find more presolar residues in 81P/Wild-2 dust impact craters.

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